MACHAKOS UNIVERSITY

University Examination 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 505: SWITCHGEAR AND PROTECTION

DATE: 21/5/2019 **TIME: 8.30-10.30 AM**

INSTRUCTIONS

Answer Question ONE and any other TWO Questions.

Make your answers Exact and Concise

QUESTION ONE (30MARKS)

a) Explain the principle of operation of a Digital Relay, giving the Relay Architecture and its merits over the other types of protective relays (6 marks)

b) A 100HP 480V 0.85pf 80% efficiency motor has starting up to 5.9 rated current up to 85 with voltage dip of 80% during starting. Design a suitable Circuit Breaker for the motor (Take 1HP=746W) (4 marks)

c) Figure 1c) shows a biased percentage differential relay applied for the protection of synchronous generator windings. The relay has 0.1A minimum pick up current and a 10 %.

i. Fault has occurred near the grounded neutral end of the generator when the generator is carrying load. As a result, the currents flowing at each end are as shown in the figure. Would the relay operate or not? (3 marks)

ii. Would the relay operate at the given value of fault current in 1c (i) above if the generator was carrying no load? (2 marks)

iii. On the same diagram, show the relay operating characteristics and the points that represent the operating and restraining currents in the relay for the two conditions in 1c(i) and 1c(ii) above (1 mark)

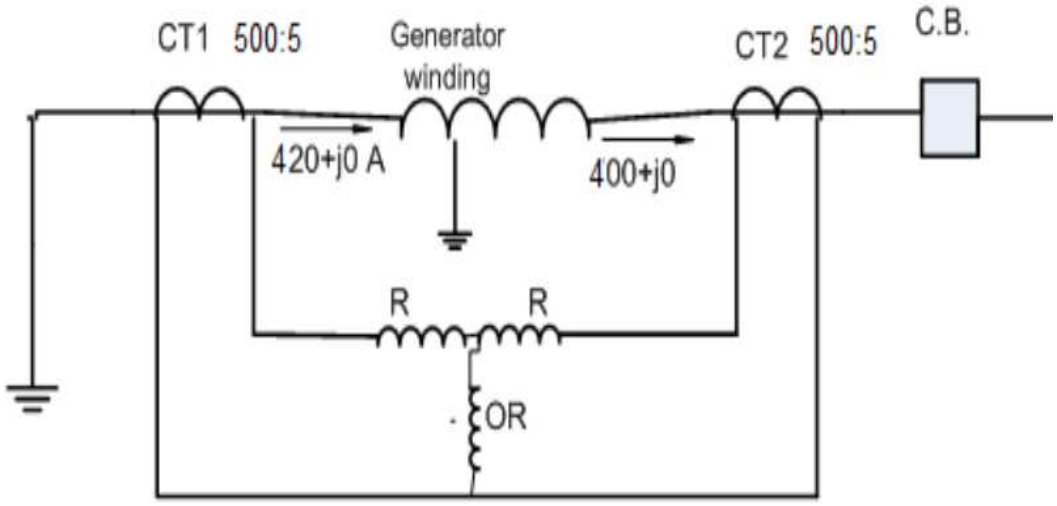


Figure Q 1c)

d) A 230 kV transmission system is as shown in Figure Q 1d). Assume that the positive – sequence impedances of lines L_{AB} and L_{BC} are 1+j 10 and 1.5 + j 15 Ω respectively. If the maximum peak load supplied by the line L_{AB} is 100 MVA at 120V with a lagging power factor of 0.9. Choose a CT ratio of 300:5.

i. Design a three – zone distance relaying system for R_{AB} impedance relay (7 marks)

ii. Draw the zones of protection and the time settings for the system (3 marks)

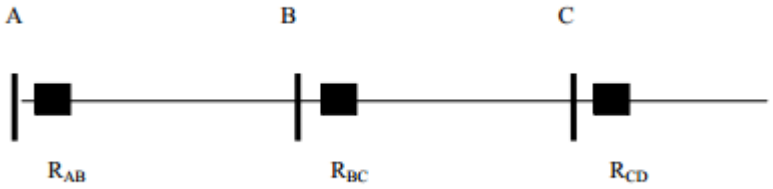


Figure Q 1d)

e) An IDMTL relay rating is 5A, 2.2sec and has a PS of 125% and TMS OF 0.6. It is connected to a supply circuit through a CT of ratio 400:5. The fault current is 4000A and

its characteristic is as shown in Figure Q 1e). Determine the time of operation of the relay (4 marks)

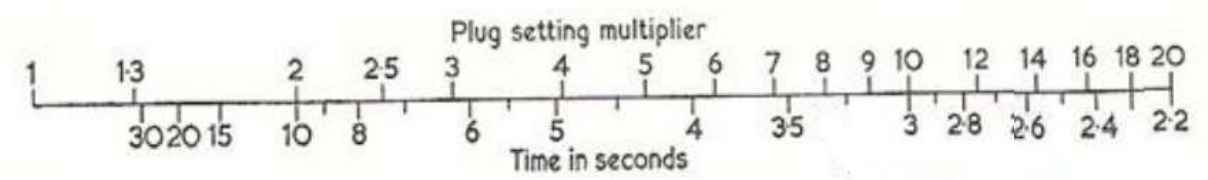


Figure Q 1e)

QUESTION TWO (20 MARKS)

a) An electromagnetic relay of attracted armature type has constants k_1 =0.6 and k_2=10 .Determine from First Principles

i. Whether the relay will operate when a current of 4A and 5A flowing through the relay winding (4 marks)

ii. The minimum current required to operate the relay (1 mark)

b) An RC circuit, used to produce time delay for a solid – state relay, is shown in Fig. 1. For a step input voltage $vi(t) = 6u(t)$, the output voltage $vo(t) = 3V$ and $C = 10\,\mu F$.

i. Determine the time delay for the following cases R = 10 k Ω and R = 1 M Ω (3 marks)

ii. Sketch the output $vo(t)$ versus time for cases 2bi) above (1 mark)

c) A balanced beam relay has a pick up current of 0.1A and a 10% slop. If the restrain coil currents are $I_{S1} = 4.2A$ and $I_{S2} = 4A$ respectively, determine whether the relay will operate or not (3 marks)

d) A radial distributor line consists of four substations designated A,B,C,and D of powers 40 , 30, 25, and 20 MW respectively . The substations are connected by transmission lines having the following impedances per phase (p.u.):

$$AB = j\,0.20\,;\ BC = j\,0.10\,;\ CD = j\,0.10$$

The system is fed at A with 33 kV from a source of negligible impedance. All circuit breakers having operating time of 0.1 second and are controlled by relays fed from current transformers with ratios: 400/5A at D, 800/5A at C, 1000/5A at B and 1500/5A at A. The characteristic of the overcurrent relay used is given in Figure Q 2d).

i. Sketch the arrangement of the system and the equivalent circuit (1.5 marks)

ii. Determine the satisfactory relay settings of breakers at D and C considering only 3-phase fault with short circuit MVA = 75 (6.5 marks)

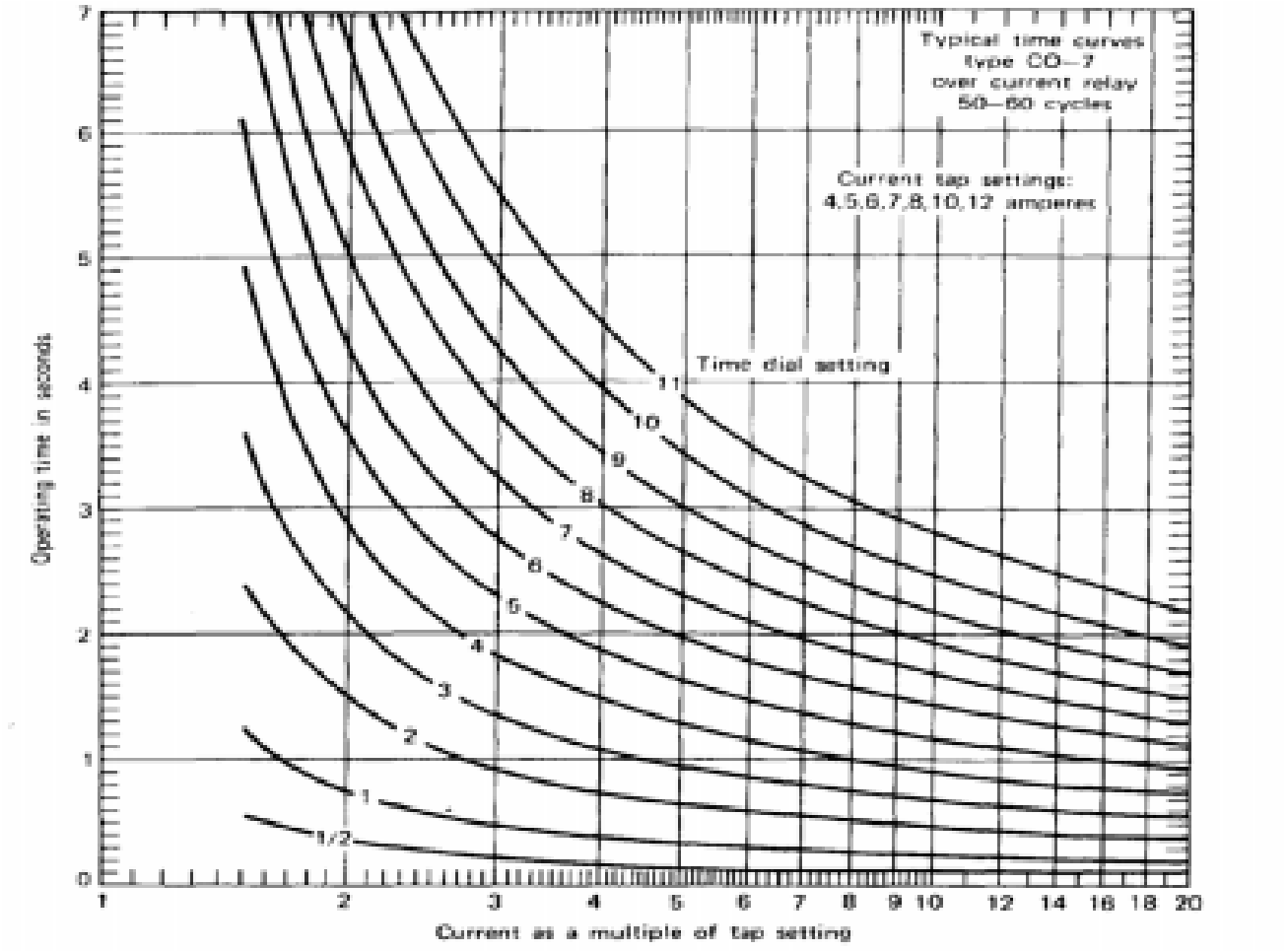


Figure Q 2d)

QUESTION THREE (20 MARKS)

a) Explain the following terms as used in Power System Protection

i. Zone of Protection (1 mark)

ii. Primary Protection (1 mark)

iii. Back Up Protection (3 marks)

iv. Zones of Overlap (1 mark)

v. Zone Boundary (1 mark)

b) A Power System has the Layout shown in Figure Q 3b). Describe the primary and the back-up protection necessary for a fault at fault points F_1, F_2 and F_3 (9 marks)

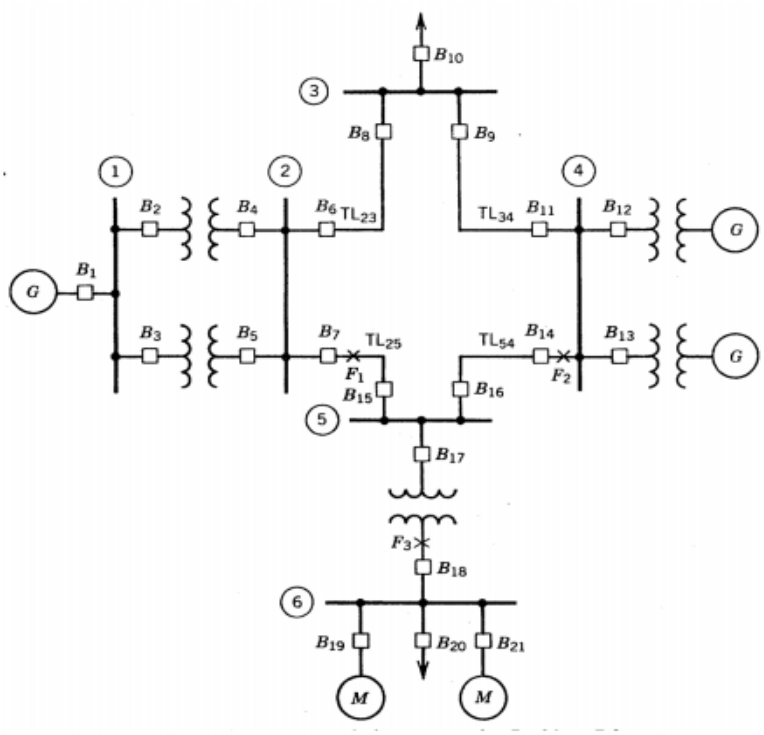


Figure Q 3 b)

c) A Power System has the Layout shown in Figure Q 3c). Determine the locations of the necessary back-up relays in the event of having a fault at the fault points F_1 and F_2 (4 marks)

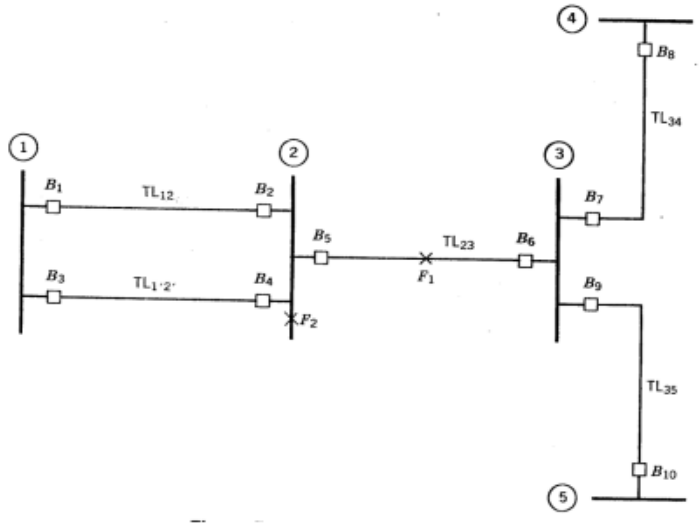


Figure Q 3 c)

QUESTION FOUR (20 MARKS)

a) The circuit of Figure Q 4a) has 600:5 class C100 CTs. The full-load current is balanced 475A per phase.

i. Determine the phase and residual relay currents for the full-load condition (2 marks)

ii. The circuit has an A phase to ground fault on the line, with fault current magnitude of 9000A .Find the phase and residual relay currents .Assume phase A is the reference phase (1 mark)

iii. The circuit has a two –phase fault with 5000A going out B phase and back in on C phase. Choose B phase current to be 0° and calculate the phase and residual relay currents (2 marks)

iv. Find the phase and residual relay currents if the circuit has a three-phase fault with 8000A per phase (2 marks)

v. Determine the CT voltage for part 4 a (iv) (three- phase fault) if the phase relay burden $Z_B = 1.2\Omega$, CT resistance $Z_S = 0.3\,\Omega$ and residual relay burden $Z_R = 1.8\,\Omega$. Neglect CT saturation and lead wire resistance (1 mark)

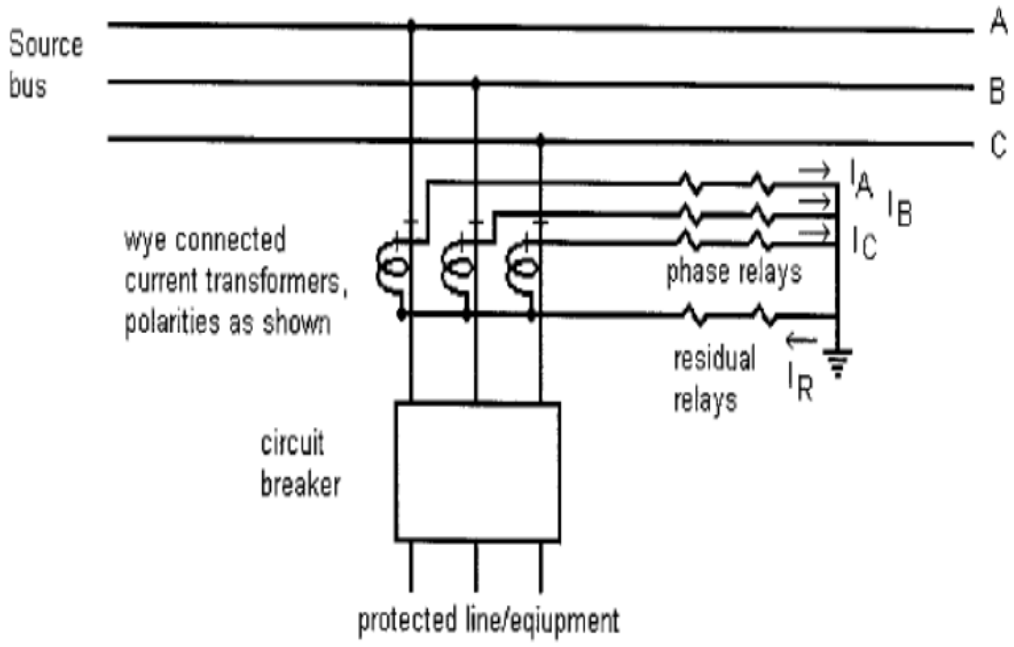


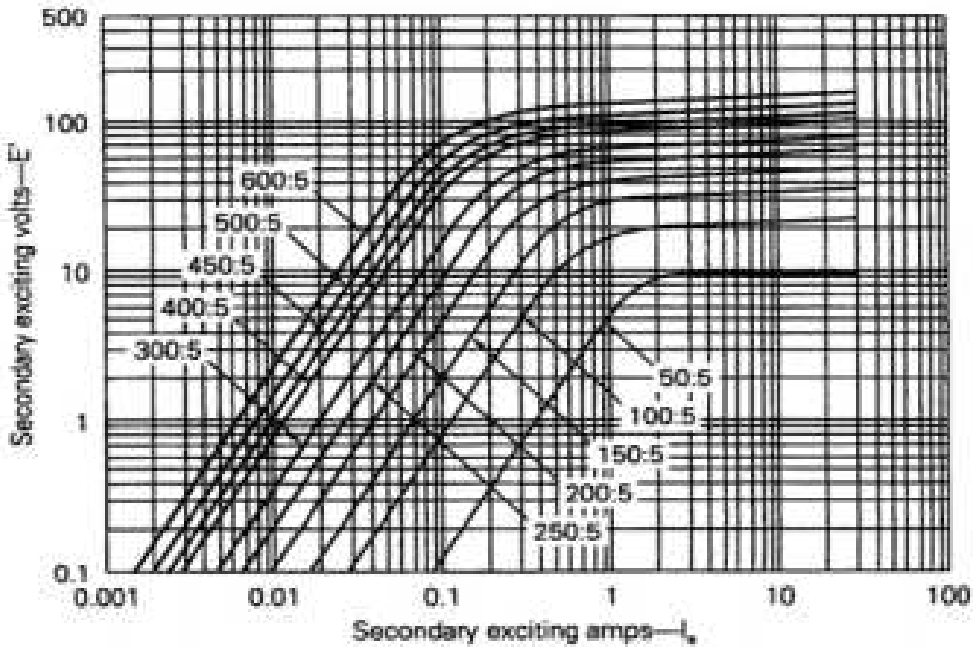
Figure Q 4a)

b) An overcurrent relay set to operate at 8A is connected to a multi ratio current transformer whose excitation curve is given in Figure Q 4b) with CT ratio of 100:5, $Z_S = 0.082\ \Omega$ and $Z_B = 0.8\ \Omega$. The core area is $2.8x10^{-3}m^2$ and $f = 50\ Hz$.

i. Will the relay detect a 200A fault current on the primary side? (3 marks)

ii. Determine whether or not the CT will saturate. The lower limit for saturation of steel is 1.2T (2 marks)

iii. Compute the percentage CT error (1 mark)



Excitation curve for a multiratio bushing current transformer.

Figure Q 4b)

c) For a 1000kVA, 11kV/400V, delta/star, three-phase transformer, determine the

i. Turns ratio of the current transformers of a nominal 5A secondary current (3 marks)

ii. Ratio k if the relay is to tolerate a mismatch in current of up to 30 % (2 marks)

QUESTION FIVE (20 MARKS)

a) Consider the system shown in Figure Q 5a). Assume that the three lines are identical with positive sequence impedance $Z_1 = j\,0.1\,p.u.$ Assume that the six line breakers are controlled by zone distance and directional only three-phase faults:

i. Determine Zone 1, Zone 2 and Zone 3 settings relays. Consider for all distance relays in per-unit (3 marks)

ii. If the CTs are rated 400:5 A , and the VTs 133kV:115 V, convert the settings in 5a i) above into ohms (3 marks)

iii. Discuss relay operations for a fault at point X, assuming X is 10% down the line L_{31} from bus 3 (3 marks)

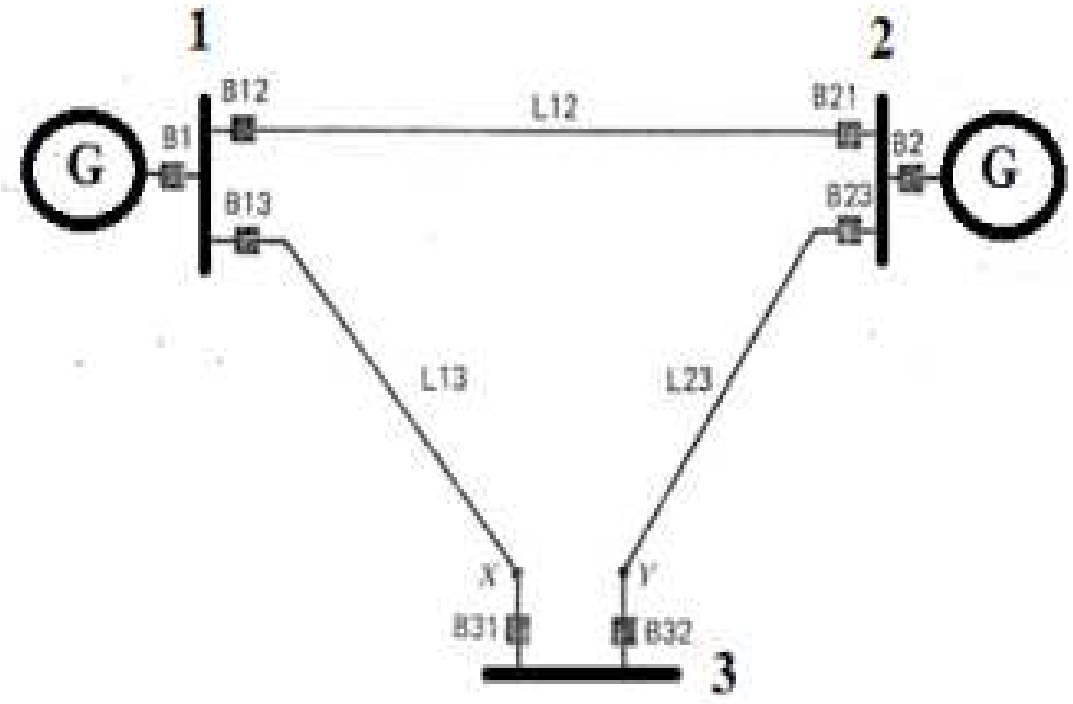


Figure Q 5a)

b) Figure Q 5b) shows a 345kV transmission loop (ring system). Table Q 5b) gives positive – sequence line impedances as well as CT and VT ratios at B_{12} for the system shown.

i. Design a three-zone impedance relay for the B_{12} breaker in vector form. Consider only a solid, three-phase fault (5.5 marks)

ii. Describe the Zones in 5b i) above (2.5 marks)

iii The maximum current for line 1-2 during emergency loading conditions is 1500 A at a power factor of 0.95 lagging. Verify that B_{12} does not trip during normal and emergency loadings (3 marks)

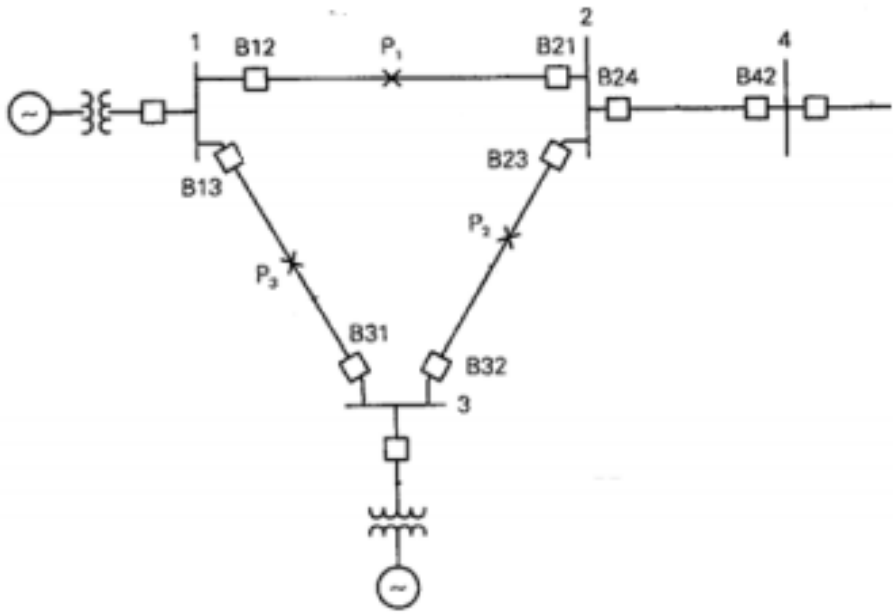


Figure Q 5b)

Table Q 5b)

Line	Positive-Sequence Impedance Ω	
1–2	8 + j50	
2–3	8 + j50	
2–4	5.3 + j33	
1–3	4.3 + j27	
Breaker	**CT Ratio**	**VT Ratio**
B12	1500:5	3000:1